# THE WATER QUALITY OF SELECTED LAKES IN THE VICINITY OF COCHRANE, ONTARIO

1975



[redacted]

Ontario

Ministry of the Environment

The Honourable
William G. Newman,
Minister

Everett Biggs,
Deputy Minister

# THE WATER QUALITY OF SELECTED LAKES IN THE VICINITY OF COCHRANE, ONTARIO.

1975

W. KELLER, WATER RESOURCES ASSESSMENT
N. CONROY, WATER RESOURCES ASSESSMENT

## PREFACE

This report is presented as a summary of the initial years' data in a water quality evaluation of selected recreational waters in the vicinity of Cochrane. The programme, including Commando, Norman, Hector and Pumphouse Lakes is ongoing and the year two data has been collected and will be reported on as a supplement. This report is intended to provide a preliminary evaluation of the trophic status of the study lakes and to serve as baseline data for the assessment of future changes.

Cochrane Enterprises, a local wood processing industry proximal to Hector, Norman and Commando Lakes has recently commenced burying wood wastes as a means of disposal. Concern has been expressed that if drainage from the disposal area reaches the lakes it could impair water quality. In response to this concern, an investigation was carried out, the results of which will be available in the near future.

Additionally, the reported fish tainting problem on Commando Lake has been investigated and the findings are available in a separate report.

TABLE OF CONTENTS

## SUMMARY AND CONCLUSIONS

The study lakes may be defined as hard-water systems based on relatively high alkalinity, conductivity and calcium concentrations. As expected of hard-water lakes, most of the major ions were present in relatively high concentrations and pH was slightly alkaline. Based on the results of chlorophyll-Secchi disc monitoring and supplementary data such as dissolved oxygen depth profiles the study lakes appear to be mesotrophic.

Areas of concern in the study lakes include evidence of high nutrient concentrations and low dissolved oxygen concentrations in the bottom waters.

Concentrations of total phosphorus in the bottom waters exceeded the level considered capable of inducing nuisance populations of algae and recorded concentrations of nitrogen were sufficiently elevated to promote nuisance growths of algae and/or aquatic macrophytes. The high concentrations of free ammonia recorded in the bottom waters of Hector and Norman Lakes are of particular concern since they, in some cases exceed the concentration considered capable of causing fish mortality. As well, concentrations of dissolved oxygen in the bottom waters of these lakes were lower than the level required for fish survival.

Due to limited data available on the quality and quantity of storm drainage entering Commando and Pumphouse Lakes, no firm conclusions on the effects of storm runoff on lake water quality may be drawn at this time. It is apparent; however, that high concentrations of many materials, including nutrients, are present in the storm runoff to these lakes and this source may constitute an extremely important input in terms of effects on water quality.

# 1.0 INTRODUCTION

## 1.1 PURPOSE AND SCOPE

During 1972, concern was expressed by the Ministry of Natural Resources, Cochrane, regarding deterioration of water quality in area lakes.

In response to this concern a 'Self Help' chlorophyll *a* Secchi disc programme was established on four lakes - Commando, Norman, Hector and Pumphouse, in the spring of 1973. Throughout the ice free season, staff of the Ministry of Natural Resources collected samples for chlorophyll *a* analyses and measured Secchi disc transparency depths on a weekly basis. During August, staff of the Ministry of the Environment carried out an intensive investigation of other water quality parameters to supplement the chlorophyll *a* Secchi disc data.

The following report provides the results of the 1973 study and discusses them in terms of general water quality and trophic status. Since the major purpose of this investigation was to provide background data to enable the determination of future changes and trends a detailed discussion of all the parameters examined is not provided.

## 1.2 DESCRIPTION OF THE STUDY AREA

The study lakes - Commando, Hector, Norman and Pumphouse, range in size from 1.2 to 14.2 ha and all are within or proximal to the boundaries of the Town of Cochrane. Figure 1.2.1 is a map of the Cochrane area showing the lakes studied and the sampling stations used. A summary of morphometric data for the study lakes is provided in Table 1.2.1. All the lakes are essentially spring fed; however, a small stream does enter Pumphouse Lake.

FIGURE 1.2.1

SKETCH MAP OF THE STUDY AREA SHOWING SAMPLING LOCATIONS

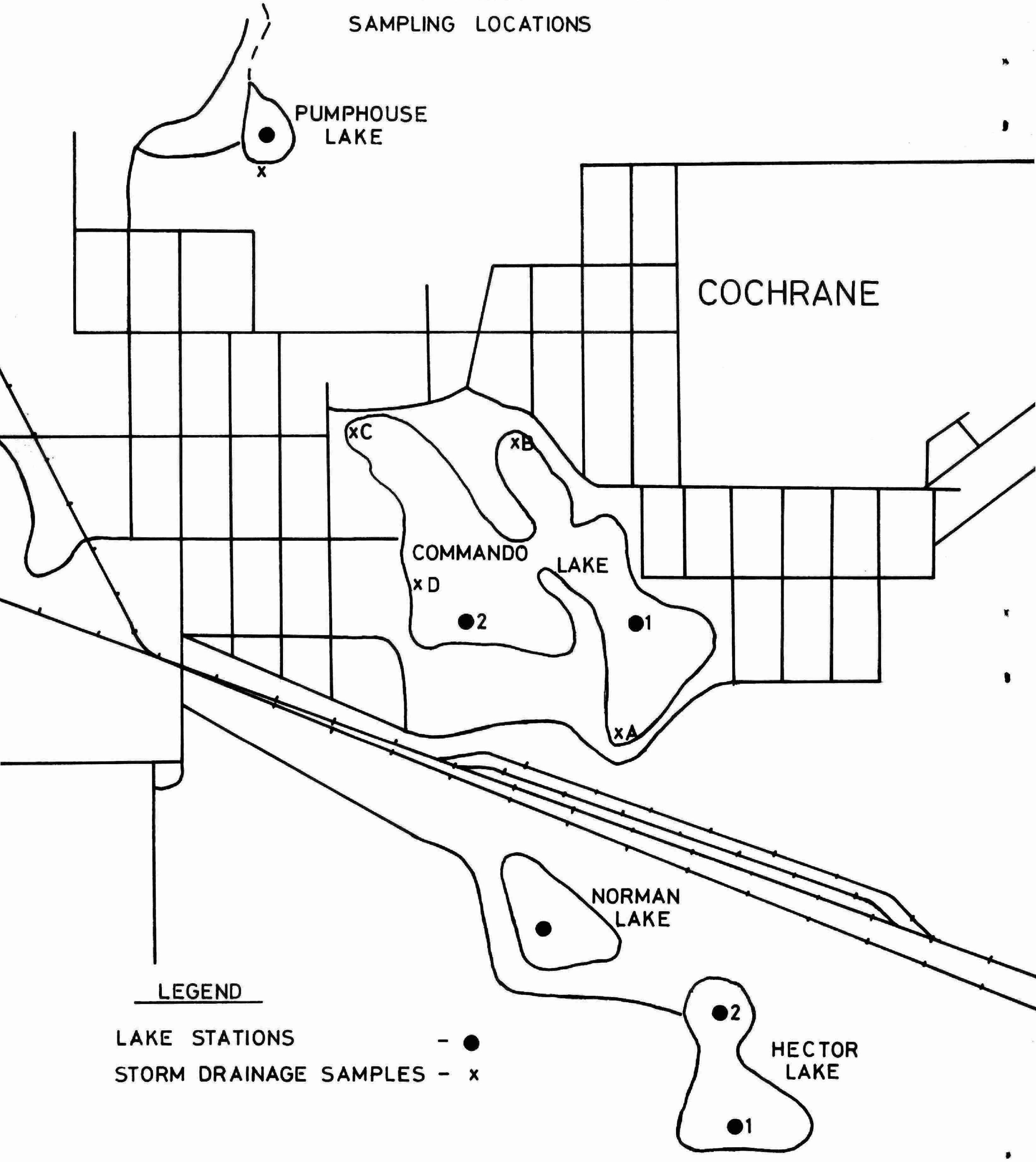


TABLE 1.2.1

MORPHOMETRIC DATA, COCHRANE AREA LAKES

| Lake | Surface Area | | Maximum Depth | | Mean Depth | | Volume | |
|---|---|---|---|---|---|---|---|---|
| | Acres | Hect. | Feet | Metres | Feet | Metres | Acre/ft. | Cu.Metres |
| Commando | 35 | 14.2 | 96 | 29.3 | 15.4 | 4.7 | 535 | $6.6 \times 10^5$ |
| Hector | 9.5 | 3.8 | 70 | 21.3 | 22.5 | 6.9 | 214 | $2.6 \times 10^5$ |
| Norman | 7.3 | 2.9 | 60 | 18.3 | 31.9 | 9.7 | 233 | $2.9 \times 10^5$ |
| Pumphouse | 3.0 | 1.2 | 26 | 7.9 | 11.3 | 3.4 | 39.5 | $4.9 \times 10^4$ |

Areas of particular public concern with regard to Commando Lake include inputs of storm runoff and the practice of burning Christmas trees on the ice during the town's winter carnival.

Hector Lake has shown signs of winter dissolved oxygen depletion and resultant loss of its fishery and it was hoped that the results of a water quality study would shed some light on the feasibility of establishing shore based aeration systems to provide an additional source of oxygen.

Pumphouse Lake receives inputs of storm runoff and in the past it has received inputs of filter wastes from the water treatment plant.

Norman Lake was included in the study to serve as a reference for the other lakes since it has not demonstrated water quality problems in the past, nor is it subjected to storm runoff from the municipal area.

# 2.0 METHODS

## 2.1 PHYSICO-CHEMICAL

During August 10 and 11, water samples were collected from specified depths with a Van Dorn sampler. Duplicate one l samples in glass bottles were collected at each depth and two depths (one m below surface and one m above bottom) were sampled at each location. Samples were retained in a portable cooler during transportation to the field laboratory where pH, alkalinity and conductivity measurements were made. Subsequently, samples were shipped to the Ministry of the Environment laboratory for analyses, including:

| | | |
|---|---|---|
| sodium | potassium | calcium |
| magnesium | phosphorus | nitrogen |
| silica | iron | |

Temperature and dissolved oxygen depth distributions were measured in the field.

Additionally, on August 10, immediately after a heavy rainstorm, samples of storm sewer effluent were collected at four locations on Commando Lake and one location on Pumphouse Lake (see Figure 1.2.1). These samples were analysed for nitrogen, phosphorus, conductivity, and phenols.

## 2.2 SECCHI DISC AND CHLOROPHYLL a

At weekly intervals throughout the summer, stations were sampled for Secchi disc transparency depths and chlorophyll a concentrations.

Secchi disc readings are taken by lowering the disc (20 cm in diameter with alternating black and white quadrants) to the depth at which it just disappears. This depth is recorded and the disc is raised to the point at which it reappears and that depth is recorded.

The point halfway between these two readings is the Secchi disc transparency depth.

Chlorophyll a samples were collected as composites through the euphotic zone (zone of significant light penetration - taken as twice the Secchi disc depth). A composite sample is collected by lowering a one l glass bottle in a weighted sampler to a depth equal to twice the Secchi disc reading and retrieving it at such a rate to allow complete filling as it reaches surface - the object being to collect water equally from all portions of the measured sampling column. Figures 2.2.1 and 2.2.2 present schematic representations of the methology of composite sampling and the composite sampler respectively.

Samples for chlorophyll a analyses were immediately stabilized with sufficient magnesium carbonate solution (2% weight to volume ratio) to elevate the pH and retard the breakdown of chlorophyll a during transportation. Samples were shipped to Toronto and were analysed in the Ministry of the Environment laboratory within 48 hours of the time of receipt.

FIGURE 2.2.1 COMPOSITE SAMPLING PROCEDURE

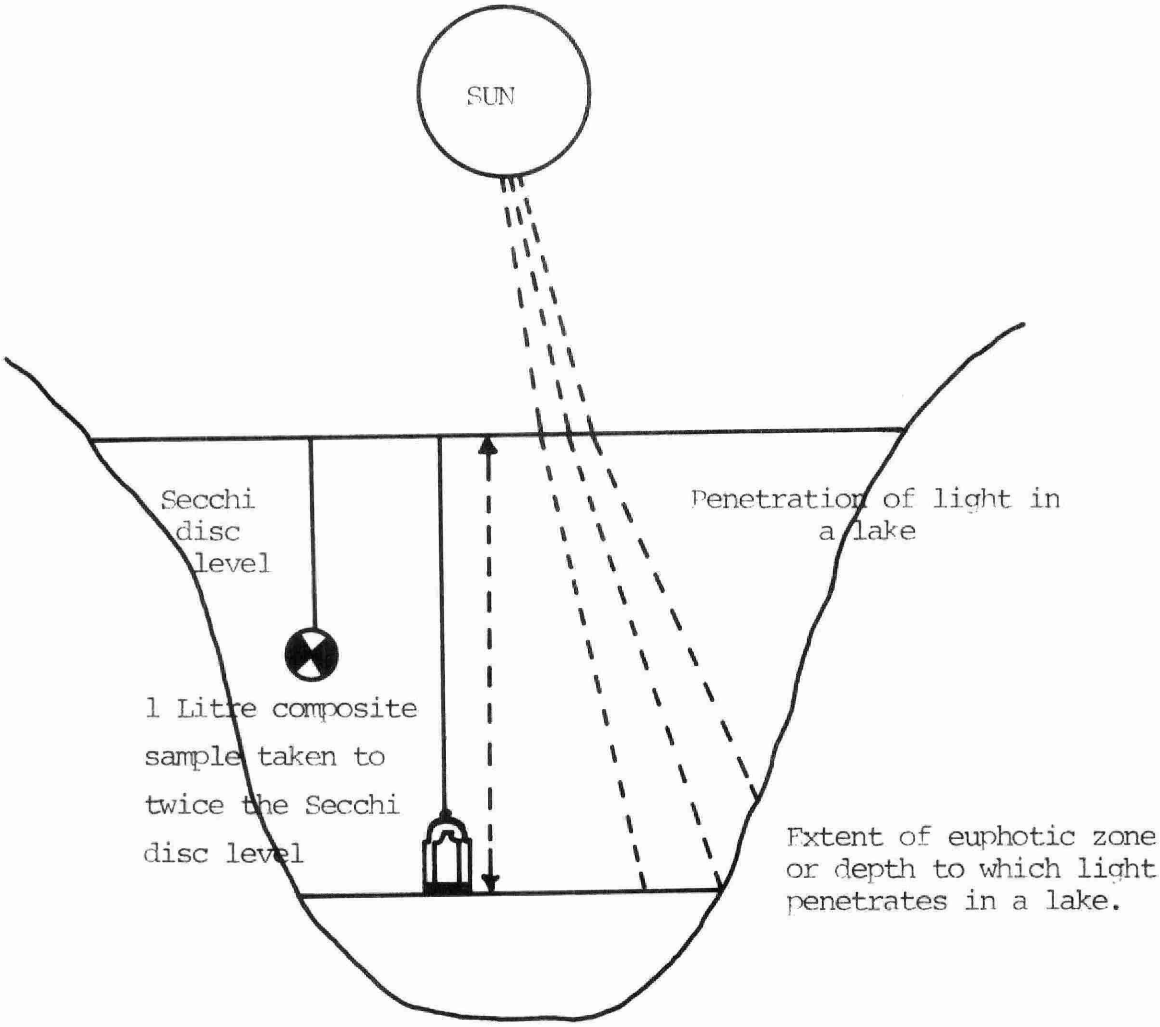
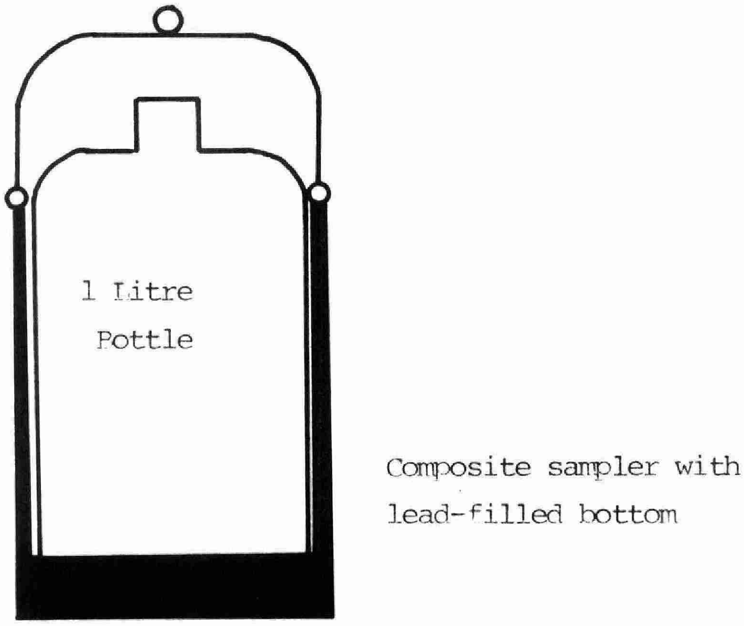



FIGURE 2.2.2 A COMPOSITE SAMPLER



# 3.0 RESULTS AND DISCUSSION

## 3.1 TEMPERATURE AND DISSOLVED OXYGEN

The results of temperature and dissolved oxygen measurements on the study lakes are provided in Table 1 of Appendix B. Temperature and dissolved oxygen depth profiles based on the data recorded in Table 1 are depicted in Figure 3.1.1.

The definition and strength of the thermocline is extremely important in determining the vertical distribution of chemical species and dissolved gases in a lake since a well established thermocline effectively isolates the surface water (epilimnion) from the bottom water (hypolimnion) acting as a barrier to vertical diffusion.

Commando Lake exhibited a well defined thermocline at both stations sampled (between 3 and 6 m and 5 and 7 m at stations #1 and #2 respectively).

Hector Lake exhibited a well defined thermocline between 3 and 6 m at both stations. It is interesting to note that a slight temperature increase occurred in the bottom waters of station #1 - no doubt due to the influence of ground water inflow.

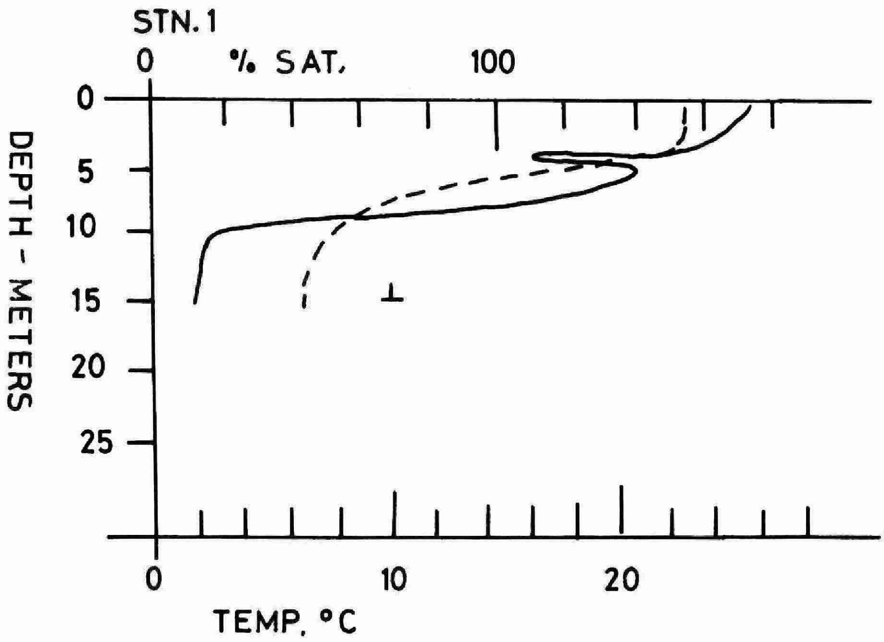
Norman Lake exhibited a well defined thermocline between 3 and 6 m and as observed at Hector Lake - station #1, a slight temperature increase near bottom was evident.

Pumphouse Lake exhibited a thermocline extending from 4 m to the lake bottom ( 7 m).

Water borne concentrations of dissolved oxygen are extremely important in a lake since fish and other aquatic life forms require oxygen for breathing.

FIGURE 3.1.1
TEMPERATURE & DISSOLVED OXYGEN DEPTH PROFILE

COMMANDO LAKE



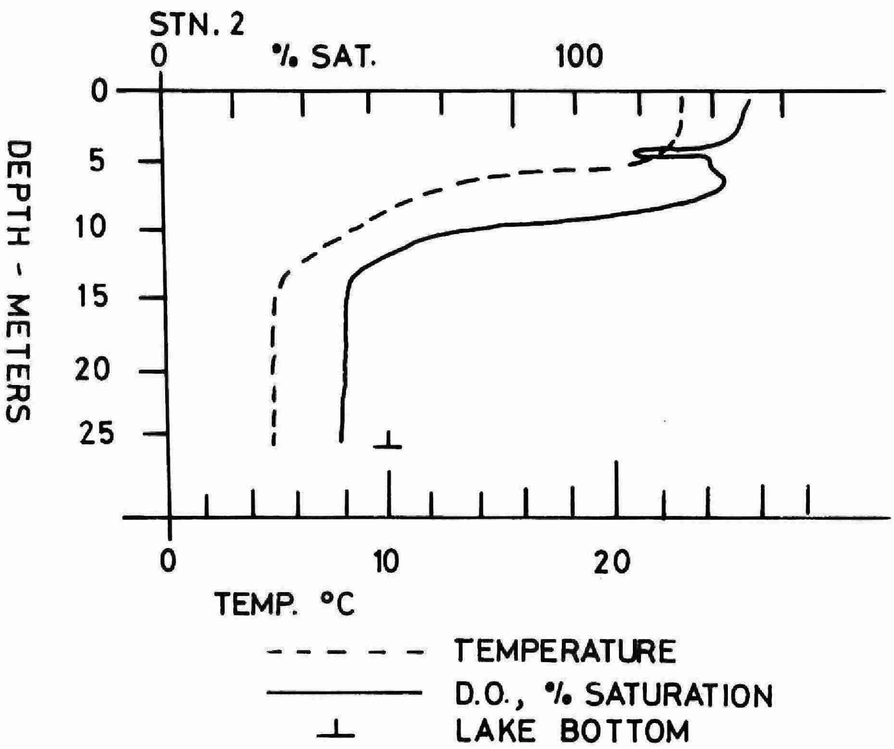



FIGURE 3.1.1 CONT'D

HECTOR LAKE

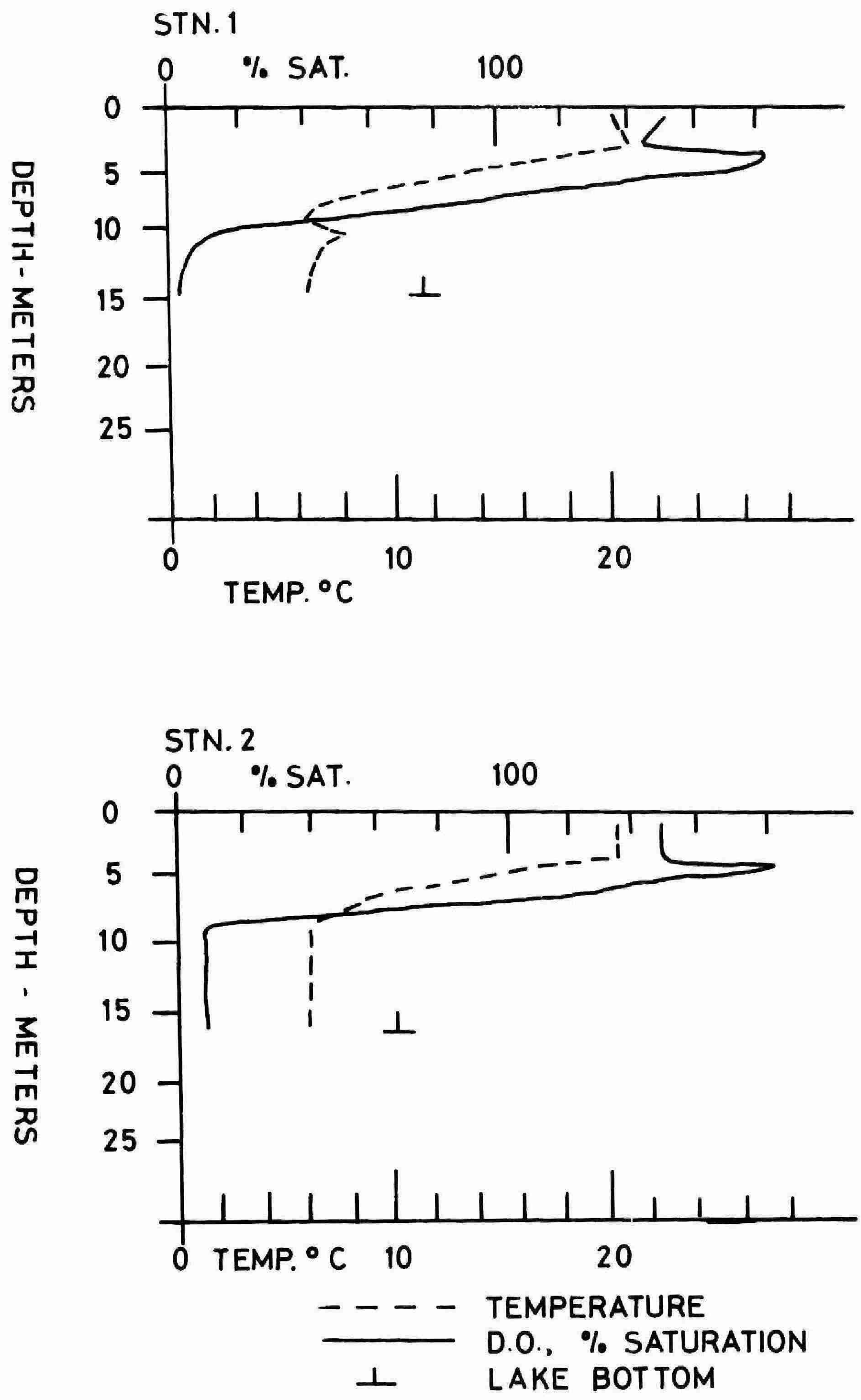
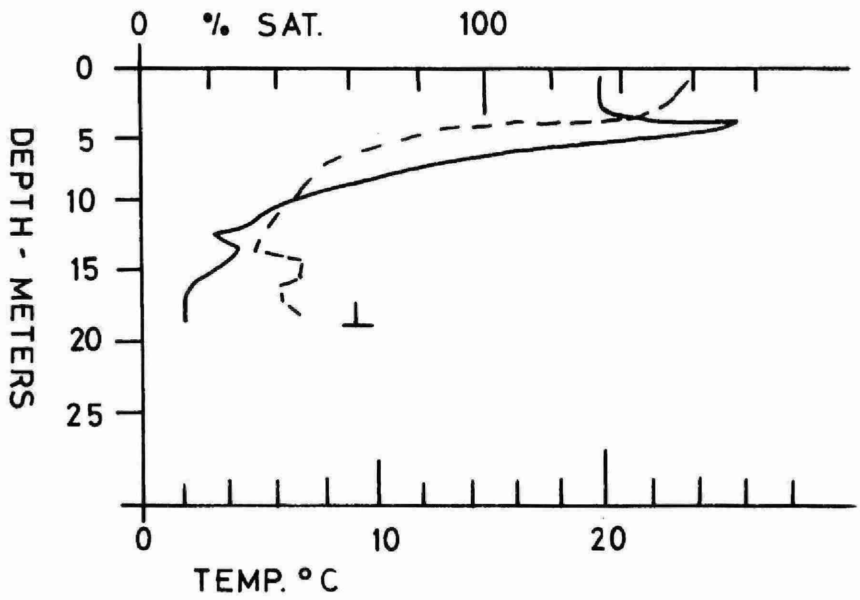
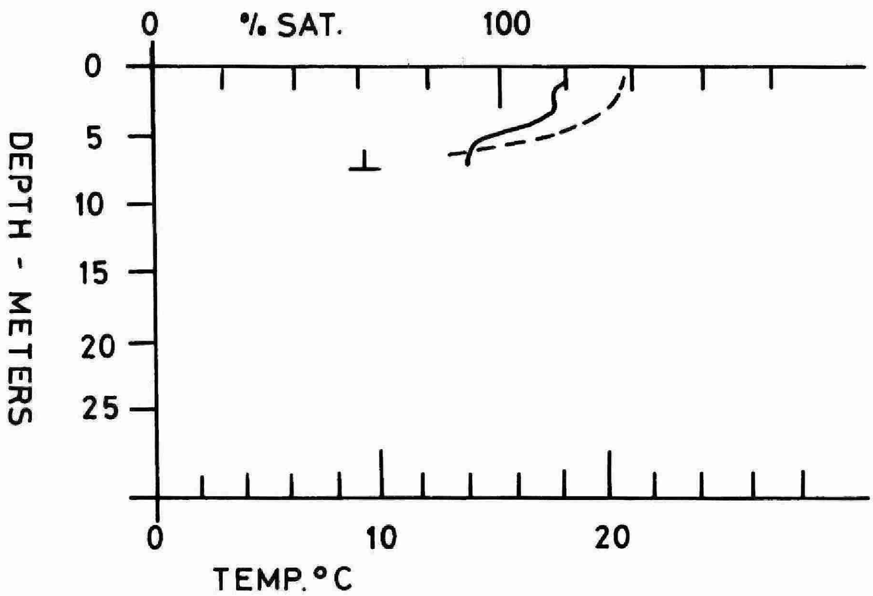


FIGURE 3.1.1 CONT'D.

NORMAN LAKE




PUMPHOUSE LAKE




- - - - TEMPERATURE
——— D.O., %. SATURATION
⊥ LAKE BOTTOM

The surface waters of the study lakes exhibited supersaturation of dissolved oxygen with concentrations ranging from 173 to 120 percent saturation. Surface water oxygen concentrations were highest in Commando and Hector Lakes and lowest in Norman and Pumphouse Lakes.

Extremely low concentrations of dissolved oxygen were recorded in the bottom waters of Commando Lake station #1 (1.9 mg $l^{-1}$), Hector Lake stations #1 and #2 (.9 mg $l^{-1}$), and Norman Lake (2.0 mg $l^{-1}$). The low dissolved oxygen concentrations observed in the hypolimnia at these locations are of extreme concern since they are well below the level considered necessary for the survival of cold-water fish species (5 to 6 mg $l^{-1}$ - Ministry of the Environment, 1972). A further concern related to the observed low dissolved oxygen concentrations is the potential for the release of nutrients from bottom sediments under anaerobic conditions. This aspect is discussed in more detail under Section 3.2.

In terms of vertical distribution, dissolved oxygen showed a significant reduction with increasing depth at all stations sampled on Commando, Hector and Norman Lakes (see figure 3.1.1). This type of distribution is termed clinograde and is generally considered typical of eutrophic lakes. Although the dissolved oxygen distributions observed in Commando, Hector and Norman lakes may be classified as clinograde based on diminishing oxygen with depth, the most striking feature of the curves depicted in Figure 3.1.1. is a pulse, or increase in dissolved oxygen in the region of the thermocline. This metalimnetic (mid-water) dissolved oxygen pulse was most pronounced in Hector and Norman lakes where dissolved oxygen concentrations in the thermocline were significantly greater than concentrations recorded at surface. Dissolved oxygen distributions exhibiting a metalimnetic (mid - water) maximum are termed

positive heterograde and are considered indicative of mesotrophy by a number of authors (see Michalski 1971).

Similarly, Commando Lake showed a significant pulse of dissolved oxygen near the thermocline, however, metalimnetic concentrations did not exceed those recorded at surface.

Pumphouse Lake exhibited a slight decrease in dissolved oxygen with depth however the distribution may be termed orthograde (essentially non-diminishing with depth).

## 3.2 WATER CHEMISTRY

The results of chemical analyses are provided in Tables II and III of Appendix B. A summary of ranges in concentration of selected parameters is provided in Table 3.2.1.

All the study lakes may be defined as hard-water systems based on the relatively high alkalinity (range =69 to 186 mg $l^{-1}$ as $CaCO_3$), conductivity (range = 189 to 760 umho cm $^{-1}$), and concentrations of calcium (range = 25 to 48 mg $l^{-1}$). As expected for hard-water lakes, most of the major ions were present in relatively high concentrations.

A general trend observed in all of the study lakes was a tendency toward higher concentrations of most variables in the bottom waters. This tendency was the most evident in Hector and Commando Lakes and indicates that significant recycling of bottom materials may be occurring in these waters. Pumphouse Lake exhibited the least variation in concentration with depth - probably due to its shallow nature resulting in more thorough mixing of waters.

pH in the surface waters of the study lakes was alkaline ranging from 7.96 (Commando Lake-Station #1) to 8.74 (Hector Lake-Station #1). Commando, Hector and Norman Lakes showed significant pH reductions in the bottom waters (approximately 1 to 2 units) however, only one station exhibited a pH below 7 (6.78 - Hector Lake, Station #2). Pumphouse Lake showed a very slight pH increase with depth (8.62 at surface to 8.69 at bottom).

TABLE 3.2.1

RANGES IN CONCENTRATION OF SELECTED VARIABLES

COCHRANE AREA LAKES, 1973

| | COMMANDO LAKE | HECTOR LAKE | NORMAN LAKE | PUMPHOUSE LAKE |
|---|---|---|---|---|
| pH | 7.14 - 8.30 | 6.78 - 8.74 | 7.01 - 8.45 | 8.62 - 8.69 |
| Alkalinity | 70 - 103 | 102 - 186 | 69 - 80 | 109 - 118 |
| Conductivity | 329 - 470 | 380 - 760 | 189 - 200 | 291 - 302 |
| Sodium | 24 - 29 | 24 - 49 | 3 - 4 | 8 |
| Potassium | 3.7 - 4.0 | 3.1 - 5.0 | 3.3 - 3.6 | 2.5 - 2.7 |
| Calcium | 27 - 42 | 26 - 48 | 25 - 27 | 25 |
| Magnesium | 3 - 4 | 9 - 16 | 4 | 14 - 15 |
| Silica | .6 - 1.4 | 1.3 - 4.0 | 1.4 - 1.6 | 3.7 - 4.3 |
| Total Phosphorus | .007- .11 | .019- 1.5 | .15- .21 | .041-.047 |
| Soluble Phosphorus | .004-.014 | .003- .81 | <.001- .075 | .028-.045 |
| Free Ammonia | .04 - .24 | <.01 - 5.2 | .04 - .34 | <.01 |
| Total Kjeldahl | .26 - .78 | .39 - 9.3 | .48 - 1.0 | .26 |
| Nitrite | .001- .49 | .002- .12 | .002 | .002-.054 |
| Nitrate | <.01 - .41 | <.01 - .23 | <.01 | .06 - .11 |
| Total Iron | .05 - .75 | <.05 - .35 | .05 - .65 | <.05 - .30 |
| Soluble Iron | <.05 - .05 | .003- .20 | .05 - .40 | <.05 |

* All values in mg $l^{-1}$ except pH (pH units) and conductivity ($\mu$mho $cm^{-1}$)

Alkalinity tended to be lowest in Norman Lake (69 to 80 mg $l^{-1}$) and highest in Hector Lake (102 to 186 mg $l^{-1}$). Commando Lake exhibited surface values similar to those recorded for Norman Lake, however, depth samples showed a significant increase in alkalinity. As well, Hector Lake exhibited a significant increase in alkalinity with depth while in Pumphouse Lake only a minor increase with depth was evident.

Commando and Hector Lake (range = 329 to 760 umho $cm^{-1}$) had conductivities ½ to 4 fold greater than the levels recorded in Norman Lake (189 to 200 umho $cm^{-1}$) and a large increase in conductivity was noted in the bottom waters. Norman Lake exhibited a slight decrease in conductivity with depth (200 umho $cm^{-1}$ at surface to 189 umho $cm^{-1}$ at bottom) while Pumphouse Lake exhibited a slight increase with depth (291 to 302 umho $cm^{-1}$).

Sodium concentrations in Commando and Hector Lakes (ranges of 24 to 29 mg $l^{-1}$ and 24 to 49 mg $l^{-1}$ respectively) were approximately ten-fold higher than values in Norman Lake (3 to 4 mg $l^{-1}$). Pumphouse Lake exhibited a sodium concentration of 8 mg $l^{-1}$.

Concentrations of potassium in the study lakes were quite similar (range = 2.5 to 5.0 mg $l^{-1}$) with a slight tendency toward higher values in Hector and Commando Lakes.

Calcium concentrations were quite uniform in the surface waters of the study lakes (25 to 30 mg $l^{-1}$) however, Commando and Hector Lakes showed approximately two-fold elevations in their bottom waters over surface levels. No significant increase in calcium concentrations with depth was noted in Norman Lake or Pumphouse Lake.

Concentrations of magnesium were found to be approximately three to four fold greater in Hector and Pumphouse Lakes (range = 9 to 16 mg $l^{-1}$) than in Commando and Norman Lakes (range = 3 to 4 mg $l^{-1}$).

Silica concentrations in the study lakes were fairly uniform, however, Commando Lake tended to have the lowest values (range = .6 to 1.4 mg $l^{-1}$) while Pumphouse Lake exhibited the highest values (range = 3.7 to 4.3 mg $l^{-1}$).

Concentrations of total iron in the surface waters were .05 mg $l^{-1}$ or less at all stations sampled, however, significant elevations of iron were apparent in the bottom waters. The highest concentrations of total iron were detected in the bottom waters of Commando Lake - Station #1 (.75 mg $l^{-1}$) and Norman Lake (.65 mg $l^{-1}$). Bottom waters at the remaining stations exhibited concentrations between .10 and .35 mg $l^{-1}$.

Concentrations of soluble iron were uniformly $<$.05 mg $l^{-1}$ in the surface waters and Commando Lake and Pumphouse Lake exhibited concentrations of .05 mg $l^{-1}$ or less throughout the water column. The highest concentration of soluble iron (.40 mg $l^{-1}$) was recorded in the bottom waters of Norman Lake. Hector Lake exhibited bottom water concentrations of .11 and .20 at stations #1 and #2 respectively.

Concentrations of phosphorous in the study lakes were found to be extremely high. Pumphouse Lake exhibited total phosphorous concentrations of .047 and .041 mg $l^{-1}$ at surface and bottom respectively while Norman Lake showed a surface concentration of .15 mg $l^{-1}$ and a bottom water concentration of .21 mg $l^{-1}$. With the exception of the bottom waters at station 1 (.11 mg $l^{-1}$) Commando Lake exhibited concentrations of total phosphorous (.007 to .014 mg $l^{-1}$) considerably lower than the other study lakes. Hector Lake exhibited total surface water phosphorous concentrations of .036 and .019 mg $l^{-1}$ at stations #1 and #2 respectively, however, a great increase was noted in the bottom waters, particularly at station #2 where an extremely high value of 1.5 mg $l^{-1}$ was recorded.

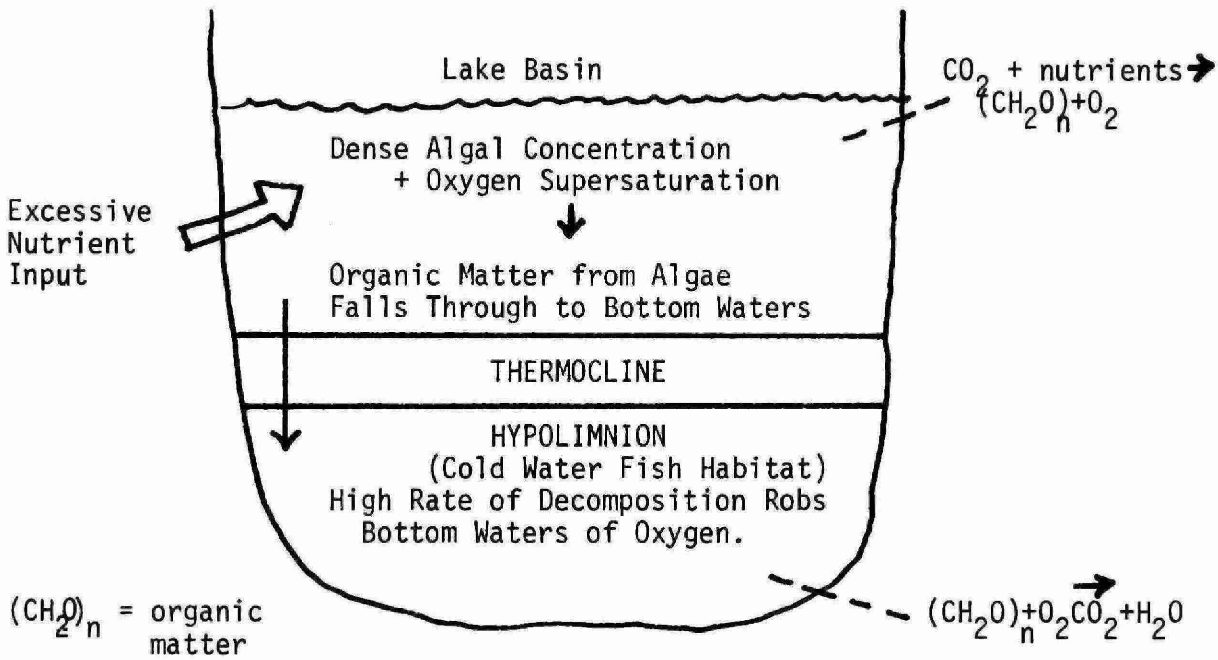
It has been indicated (see Michalski and Conroy, 1973) that troublesome levels of algae can be expected to materialize when mean total phosphorous concentrations during the ice free season exceed .020 mg $l^{-1}$. With the exception of Commando Lake - station #2, phosphorous concentrations at all stations greatly exceed .020 mg $l^{-1}$ in their bottom waters. As well, this level was generally closely approached or exceeded in surface waters. The high total phosphorous concentrations found in the bottom waters of Commando Lake - station #1 (.11 mg $l^{-1}$), Hector Lake - stations #1 and #2 (.16 and 1.5 mg $l^{-1}$) and Norman Lake (.21 mg $l^{-1}$) are higher than values reported by Conroy, Keller and Bangay, 1974 for Portage Bay of Lake Temagami - an area experiencing periodic intensive blooms of blue-green algae.

A further concern related to the high recorded phosphorous concentrations is the potential for nutrient induced algae blooms to deplete dissolved oxygen concentrations. The operating mechanism causing such dissolved oxygen reductions is depicted in Figure 3.2.1.

FIGURE 3.2.1

SIMPLIFIED REPRESENTATION OF MECHANISM

CAUSING BOTTOM WATER DISSOLVED OXYGEN DEPLETION.



As indicated in Section 3.1.1, low dissolved oxygen concentrations were recorded in the bottom waters of Commando, Hector and Norman Lakes.

Brydges, 1971, has shown that under anaerobic conditions nutrients - particularly phosphorous, may be released from sediments into the bottom waters. The ratio of total iron to total phosphorous in the bottom waters provides an indication of the extent of this recycling process. Low ratios indicate a significant degree of recycling while high ratios indicate that significant recycling is not occurring. A summary of iron: phosphorous ratios at stations in the study lakes exhibiting anaerobic conditions in their bottom waters is presented in Table 3.2.2.

TABLE 3.2.2

FE:P RATIOS IN THE STUDY LAKES

| LOCATION | FE:P RATIO |
|---|---|
| Commando Lake Stn. #1 | 6.8 |
| Hector Lake Stn #1 | 1.0 |
| Hector Lake Stn.#2 | .2 |
| Norman Lake | 3.1 |

As indicated in Table 3.2.2, iron to phosphorous ratios in the study lakes were extremely low ranging from .2 to 6.8 - lower than the value (10.1) reported by Michalski, Johnson, and Veal, 1973, for Gravenhurst Bay - an area demonstrating severe eutrophication problems.

Concentrations of nitrogen in the study lakes are also of concern. Free ammonia concentrations were found to be relatively low in surface waters (range = <.01 to .06 mg $l^{-1}$), however, considerably greater concentrations were detected in the bottom waters of Commando Lake - station #1, and Hector and Norman Lakes (range = .24 to 5.2 mg $l^{-1}$). Hector Lake exhibited extremely high free ammonia concentrations of .95 and 5.2 mg $l^{-1}$ at stations #1 and #2 respectively.

Concentrations of Kjeldahl nitrogen corresponded directly to free ammonia concentrations in that high ammonia values occurred at the same locations exhibiting high Kjeldahl values. Kjeldahl nitrogen concentrations in the surface water ranged from .26 mg $l^{-1}$ (Pumphouse Lake and Commando Lake station 1) to .63 mg $l^{-1}$(Hector Lake station #1). Bottom water concentrations showed the greatest elevation in Hector Lake (1.7 and 9.3 mg $l^{-1}$ at stations #1 and #2 respectively).

Nitrite concentrations ranged from .001 to .49 mg $l^{-1}$. Extremely high concentrations of .49 mg $l^{-1}$ and .12 mg $l^{-1}$ occurred in the bottom waters of Commando Lake station #1 and the surface waters of Hector Lake station #2 respectively. High values were also recorded in the bottom waters of Hector Lake station #1 and the surface waters of Pumphouse Lake (.050 and .054 mg $l^{-1}$ respectively). Nitrite concentrations are normally elevated only when dissolved oxygen is depressed and this is generally the case in the study lakes.

Surface concentrations of nitrate were found to be generally low ( $<$01 mg $l^{-1}$) with the exception of Hector Lake station #2 (.23 mg $l^{-1}$) and Pumphouse Lake (.11 mg $l^{-1}$). Bottom water nitrate concentrations were also generally low with most values within the range$<$.01 to .06 mg $l^{-1}$. Values exceeding this range were recorded at Commando Lake - stations #1 and #2 (.41 and .19 mg $l^{-1}$ respectively).

The high concentrations of nitrogen in the study lakes are of concern since they are sufficiently elevated to promote nuisance growths of algae and/or aquatic macrophytes.

As well, the high concentrations of free ammonia recorded in the bottom waters of Hector Lake - stations #1 and #2, and Norman Lake (.95, 5.2 and .34 mg $l^{-1}$ respectively) are of particular concern since they approach or in some cases greatly exceed the level reported lethal to some species of fish (McKee and Wolf, 1963).

## 3.3 CHLOROPHYLL a - SECCHI DISC

The results of chlorophyll a - Secchi disc monitoring are provided in Table IV of Appendix B. A summary of ranges and mean values for the study lakes is provided in Table 3.3.1.

TABLE 3.3.1

SUMMARY OF SECCHI DISC AND CHLOROPHYLL a DATA, COCHRANE AREA LAKES, 1973

| Lake | Secchi Disc (Metres) | | Chlorophyll a | | # of Samples |
|---|---|---|---|---|---|
| | Range | Mean | Range | Mean | |
| Commando | 3.3 - 8.7 | 5.0 | 0.5 - 2.5 | 1.2 | 13 |
| Hector | 2.7 - 5.0 | 3.4 | 1.3 - 10.5 | 5.3 | 9 |
| Norman | 2.4 - 4.8 | 3.7 | 0.8 - 3.0 | 2.1 | 9 |
| Pumphouse | 3.4 - 5.1 | 4.2 | 0.3 - 11.0 | 2.5 | 6 |

As indicated in Table 3.3.1, mean Secchi disc transparency depths were highest in Commando and Pumphouse Lakes (5.0 and 4.2 m respectively) and lowest in Hector and Norman Lakes (3.4 and 3.7 m respectively).

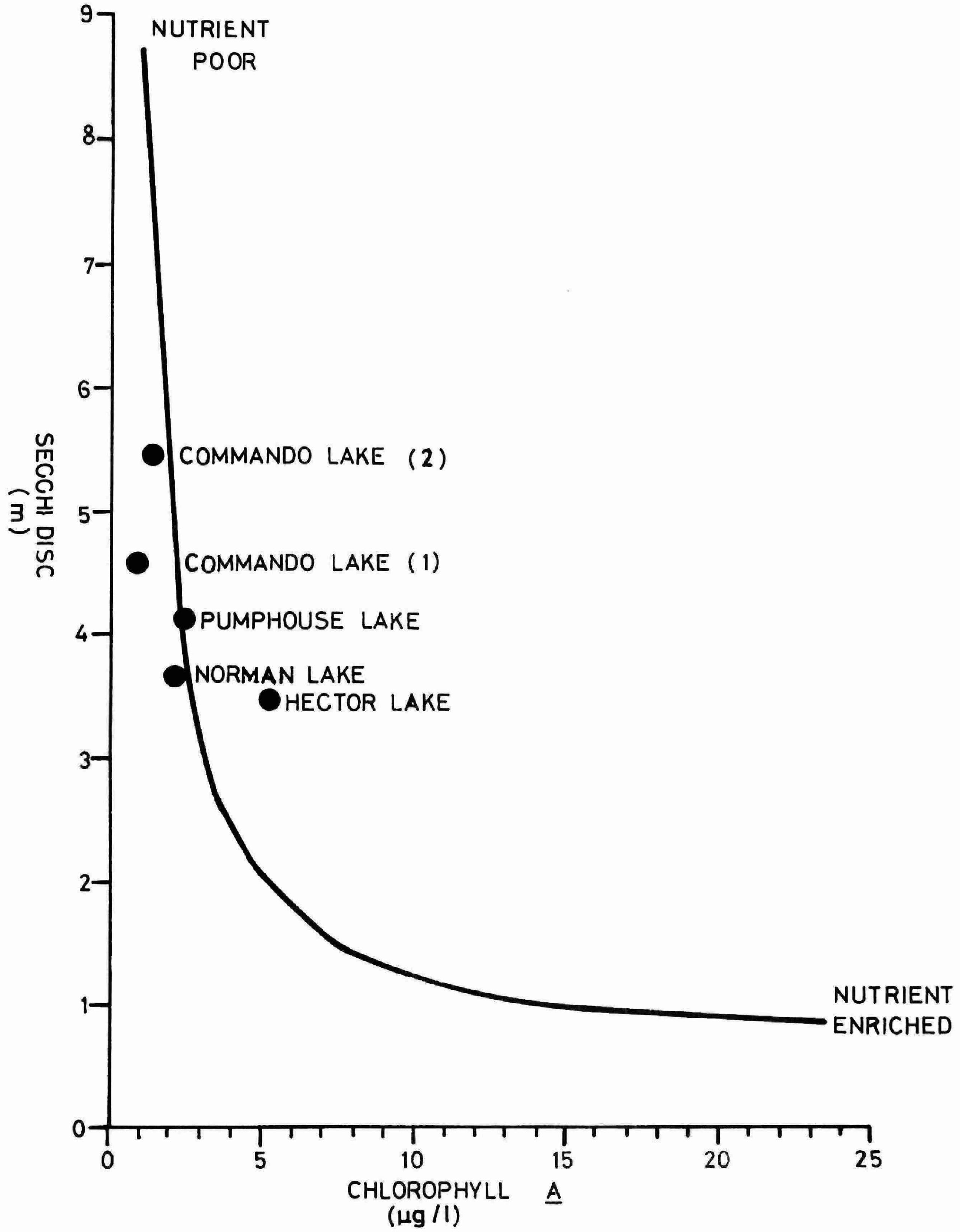
Research has shown (see Vallentyne 1969) that lakes with Secchi disc transparencies of less than 3 m are eutrophic while lakes exhibiting Secchi disc readings exceeding 6 metres are oligotrophic. By this criteria, all the study lakes appear in a mesotrophic category with Hector and Norman Lakes exhibiting Secchi disc values indicative of advanced mesotrophy while Commando Lake appears in an early mesotrophic stage. It should be noted (see Table IV of the Appendix) that Secchi disc values in the eastern portion of Commando Lake (station #1) were significantly lower (mean value - 4.6 m) than transparencies in the western portion (station #2, mean value - 5.4 m). Pumphouse Lake appears in an intermediate stage of mesotrophy based on Secchi disc transparencies (mean 4.2 m).

The concentration of chlorophyll a, the main photosynthetic green pigment in plants, provides an indication of the extent of biological activity in a lake. As indicated in Table 3.3.1., mean concentrations of chlorophyll a in the study lakes ranged from 1.2 to 5.3 ug $l^{-1}$ (Commando and Hector Lakes respectively). Norman and Pumphouse Lakes exhibited intermediate concentrations of chlorophyll a (2.1 and 2.5 ug $l^{-1}$ respectively). As expected, the highest concentrations of chlorophyll a generally occurred at the stations exhibiting the lowest Secchi disc readings and vice versa.

Experience has indicated (see Michalski and Conroy 1972) that chlorophyll a values below 5 ug $l^{-1}$ indicate low to moderate algal densities characteristic of oligotrophic lakes while concentrations greater than 10 ug $l^{-1}$ reflect high algal densities typical of eutrophic lakes. With the exception of Hector Lake (mean concentration 5.3 ug $l^{-1}$) all the study lakes exhibited chlorophyll a concentrations indicative of an oligotrophic status (range in mean concentrations = 1.2 to 2.5 ug $l^{-1}$). It should be noted that the chlorophyll a concentrations in Hector Lake, although significantly higher than those found in other study lakes, closely approach the level ($<$ 5 ug $l^{-1}$) considered typical of oligotrophic lakes.

The Ministry of the Environment has indicated that a near hyperbolic relationship exists between chlorophyll a concentrations and Secchi disc transparencies, which can be used to bracket the trophic status of a lake. Figure 3.3.1 is a graph of this relationship with the values for the study lakes included. It appears from the graph that the study lakes are mesotrophic in nature. Hector Lake is in a significantly more advanced stage of mesotrophy than the other study lakes while Commando Lake tends toward a very early mesotrophic status, particularly at station #2.

FIGURE 3.3.1 — THE RELATIONSHIP BETWEEN CHLOROPHYLL A & SECCHI DISC AS DETERMINED FROM ONTARIO LAKES



## 3.4 STORM DRAINAGE

The results of chemical analyses of storm sewer effluent from four locations entering Commando Lake and one location on Pumphouse Lake are provided in Table 3.4.1.

TABLE 3.4.1

RESULTS OF ANALYSES OF STORM SEWER EFFLUENT, COCHRANE AREA, AUGUST 10, 1973.

| Location | Phosphorous | | Nitrogens | | | | Cond. | Phenols |
|---|---|---|---|---|---|---|---|---|
| | Total | Soluble | $NH_3$ | Kjeldahl | $NO_2$ | $NO_3$ | | |
| Commando L | | | | | | | | |
| Location A | .16 | .013 | .03 | .88 | .006 | <.01 | 110 | 0 |
| Location B | .074 | .017 | .22 | .81 | .029 | .02 | 108 | 2 |
| Location C | .090 | .014 | .03 | .48 | .014 | .07 | 295 | 3 |
| Location D | .18 | .001 | .02 | 1.1 | .003 | <.01 | 259 | 0 |
| Pumphouse L | .14 | .056 | .01 | .62 | .004 | .06 | 560 | 2 |

Note: All values expressed as mg $l^{-1}$ except conductivity (umho $cm^{-1}$) and phenols (ug $l^{-1}$)

As indicated in the table, concentrations of total phosphorous in storm runoff were very high at all locations sampled (.074 to .18 mg $l^{-1}$). From .001 to .056 mg $l^{-1}$ of the total phosphorous at these locations was in the soluble form. Phosphorous concentrations in storm runoff to Commando Lake were within the range recorded in the lake water while runoff to Pumphouse Lake exhibited a phosphorous concentration significantly greater than the lake water.

With the exception of location B on Commando Lake (.22 mg $l^{-1}$) concentrations of free ammonia in the storm drainage were generally low (.01 to .03 mg $l^{-1}$) however, concentrations of Kjeldahl nitrogen were quite high ranging from .48 to 1.1 mg $l^{-1}$. Nitrite concentrations in the storm drainage ranged from .003 to .029 mg $l^{-1}$ with the highest concentrations in evidence at locations B and C on Commando Lake (.029 and .014 mg $l^{-1}$ respectively). Nitrate concentrations ranged from <.01 to .07 mg $l^{-1}$ with the highest

concentrations occurring at Commando Lake (.07 mg $l^{-1}$) and Pumphouse Lake (.06 mg $l^{-1}$).

The conductivity of storm runoff to Commando Lake ranged from 108 to 295 umho and was in all cases lower than the conductivity of the lake water (ranged 329 to 470 umho cm $^{-1}$, see Table 3.1.1), although at stations C and D the surface water concentration in the lake was approached. Storm drainage to Pumphouse Lake exhibited a conductivity of 560 umho cm $^{-1}$ approximately twice that of the lake water (291 to 302 umho cm $^{-1}$).

Phenols were found to be absent in the storm runoff at locations A and D on Commando Lake while values of 2, 3 and 2 ug $l^{-1}$ were recorded at locations B and C on Commando Lake and Pumphouse Lake respectively.

It should be borne in mind that the results presented above are based on a single set of samples taken at one point in time and may not reflect totally the overall picture since storm drainage is, by nature, variable depending on factors such as quantity and duration of rainfall. It is evident, however, that storm runoff entering Commando and Pumphouse Lakes contains high concentrations of many elements as indicated by the high conductivity values recorded (108 to 560 umho cm $^{-1}$). In a study by Kramer, 1973, it was found that the mean conductivity of precipitation in eastern Ontario was 45 umho cm$^{-1}$ thus, it is evident that a major portion of the materials present in the runoff is obtained from the surface of the drainage basin. Since the lakes are essentially closed systems without surface inflows or outflows the contribution of materials from storm drainage may be an extremely important input. It should be noted that the effects of groundwater inflows and outflows are unknown at this time.

The high concentrations of phosphorous, Kjeldahl nitrogen and nitrite are of particular concern due to the potential of these substances to accellerate the eutrophication process in lakes. Inputs of those elements from storm drainage may be contributing to the extremely high nutrient concentrations recorded in the study lakes and the resultant adverse conditions such as the observed low dissolved oxygen concentrations. However, further investigation will be required to identify and quantify nutrient inputs from storm drainage.

The presence of phenols in some of the storm sewer effluents is of concern due to the potential of this substance to cause taste and odour in fish flesh. In this regard, reports of tainted fish from Commando Lake have been received and a fish flavour evaluation programme has been implemented.

# R E F E R E N C E S   C I T E D

Brydges, T. G., 1971. Eutrophication of recreational lakes - a possible explanation. Ministry of the Environment.

Conroy, N. I., W. Keller and A. Bangay, 1974. The Water Quality of Lake Temagami. Ministry of the Environment.

Kramer, J. R., 1973. Fate of atmospheric sulphur dioxide and related substances as indicated by chemistry of precipation. McMaster University, Hamilton.

McKee, J. E. and H. W. Wolf. 1963. Water Quality Criteria. California State Water Resources Control Board, Sacremento, California.

Michalski, M.F.P., 1971. Status of enrichment of Walkers' Lake - Lake of Bays. Ontario Water Resources Commission.

_______________ - and N. I. Conroy, 1972. Water Quality evaluation for the Lake Alert Study. Ministry of the Environment.

_______________ - and N. I. Conroy, 1973. The oligotrophication of Little Otter Lake - Parry Sound District. Ministry of the Environment.

_______________ - M. Johnson and D. Veal, 1973. Muskoka Lakes Water Quality evaluation. Ministry of the Environment.

Ministry of the Environment, 1972. Guidelines and Criteria for Water Quality Management in Ontario.

Vallentyne, J. R. 1969. The process of eutrophication and criteria for trophic state determination. Modelling the eutrophication process. - proceedings of workshop, St. Petersburg, Florida, Nov. 21 - pg. 57 - 67.

## ACKNOWLEDGEMENTS

It is with pleasure that the participation of the following persons and agencies is acknowledged.

Staff of the Ministry of Natural Resources carried out the weekly chlorophyll *a* - Secchi disc monitoring. Their participation was essential since this data formed the foundation of the trophic status evaluation.

Kristin Day, Julie Delabbio and Jerry Zuchlinski, summer students with the Ministry of the Environment, assisted in the collection of the intensive water quality information.

# A P P E N D I X   A

## GLOSSARY

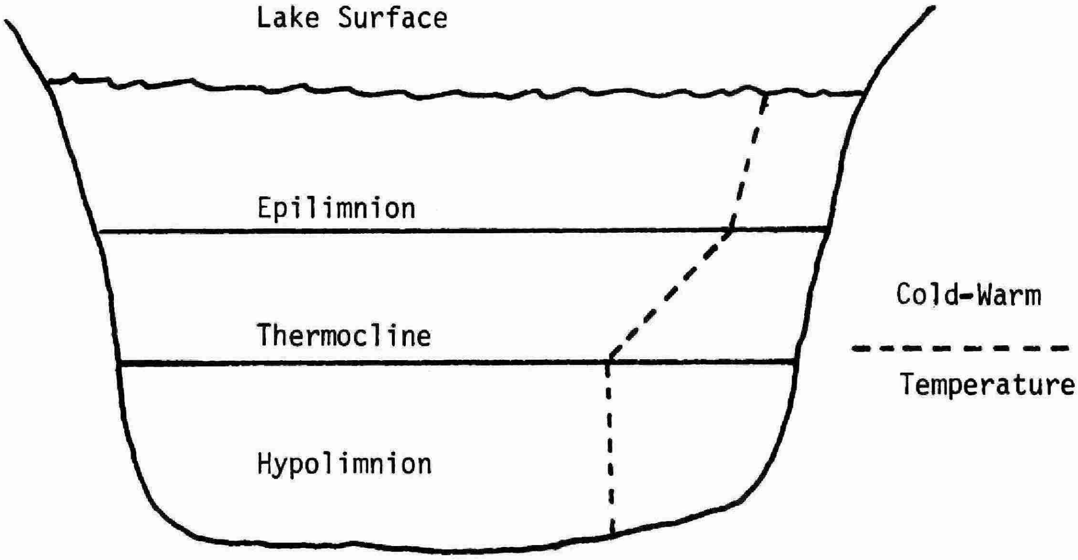
# G L O S S A R Y

ACIDIFICATION - the process of becoming more acid - of increasing the hydrogen concentration. The standard measure of the hydrogen ion concentration is pH.

EPILIMNION - lakes which show thermal stratification have three distinct layers. The upper layer of water in which the temperature is relatively uniform is the epilimnion (see Figure A).

Figure A

Sketch of cross-section of theoretical lake during thermal stratification indicating water layers and temperature distribution.




EUPHOTIC ZONE - the intensity of light diminishes as it passes through water until at some depth there is insufficient light to carry on photosynthesis. This zone of significant light penetration is the euphotic zone.

EUTROPHIC - lakes are classified into three categories on the basis of the biological activity - those with high biological activity and large nutrient concentrations are eutrophic. Characteristically eutrophic lakes are shallow, warm and highly turbid (see oligotrophic, mesotrophic, and trophic status).

EUTROPHICATION - the process by which lakes become increasingly enriched in nutrients. It refers to the entire complex of changes which accompany nutrient enrichment including dense growth of algae and aquatic weeds.

HYPOLIMNION - the uniformly cold layer of water lying beneath the thermocline in thermally stratified lakes, see Figure A.

MESOTROPHIC - those lakes with a moderate supply of nutrients and moderate biological activity, ie. a trophic status lying between oligotrophic and eutrophic.

OLIGOTROPHIC - lakes with a meagre supply of nutrients and low biological activity. Characteristically oligotrophic lakes are deep, cold water, highly transparent bodies of water.

pH - A measure of acidity/alkalinity on a scale from 0-14 where 7.0 is neutral and 6.9-0 indicates increasing acidity and 7.1 to 14 increasing alkalinity.

| Strongly Acid | Acid | Neutral | Basic | Strongly Basic |
|---|---|---|---|---|
| 0-3.9 | 4-6.9 | 7.0 | 7.1-10 | 10.1-14 |

Natural Water

THERMOCLINE - the mid layer of water in thermally stratified bodies of water in which the rate of change of temperature is a maximum.

TROPHIC STATUS - lakes classified on the basis of the degree of nutrient enrichment and biological activity into three integrating types; oligotrophic, mesotrophic and eutrophic. Additions of nutrients to infertile lakes (oligotrophic) tend to make them mesotrophic and with continued enrichment they will become eutrophic.

# A P P E N D I X  B

## DATA TABLES

TABLE I

RESULTS OF DISSOLVED OXYGEN AND TEMPERATURE MEASUREMENTS
COCHRANE AREA LAKES

| LOCATION | DATE | DEPTH | TEMPERATURE (°C) | DISSOLVED OXYGEN (% Saturation) | DISSOLVED OXYGEN ($mg\ l^{-1}$) |
|---|---|---|---|---|---|
| COMMANDO | | | | | |
| Station 1 | 11/8/73 | 1 m | 23.0 | 173 | 15.0 |
| | | 3 m | 22.8 | 165 | 14.1 |
| | | 4 m | 21.3 | 110 | 9.4 |
| | | 5 m | 16.0 | 140 | 13.3 |
| | | 6 m | 11.8 | 138 | 14.4 |
| | | 7 m | 10.0 | 131 | 14.2 |
| | | 8 m | 9.0 | 97 | 10.8 |
| | | 9 m | 7.6 | 64 | 7.8 |
| | | 10 m | 7.0 | 20 | 2.3 |
| | | 11 m | 7.0 | 16.3 | 2.0 |
| | | 12 m | 6.5 | 15.0 | 1.9 |
| | | 14 m | 6.5 | 15.0 | 1.9 |
| Station 2 | 11/8/73 | 1 m | 22.8 | 172 | 15.2 |
| | | 3 m | 22.8 | 167 | 14.8 |
| | | 4 m | 22.7 | 136 | 11.8 |
| | | 5 m | 22.0 | 160 | 13.6 |
| | | 6 m | 18.0 | 160 | 14.4 |
| | | 7 m | 12.0 | 162 | 17.0 |
| | | 8 m | 10.7 | 158 | 17.0 |
| | | 9 m | 8.7 | 113 | 12.8 |
| | | 10 m | 7.5 | 92 | 10.6 |
| | | 11 m | 6.5 | 73 | 8.2 |
| | | 12 m | 6.0 | 68 | 8.2 |
| | | 13 m | 5.8 | 59 | 7.2 |
| | | 14 m | 5.3 | 53 | 6.4 |
| | | 18 m | 5.0 | 52 | 6.3 |
| | | 24 m | 5.0 | 48 | 6.0 |
| HECTOR | | | | | |
| Station 1 | 11/8/73 | 1 m | 19.9 | 152 | 13.3 |
| | | 3 m | 20.3 | 144 | 12.4 |
| | | 4 m | 17.2 | 182 | 17.0 |
| | | 5 m | 13.1 | 174 | >17.0 |
| | | 6 m | 8.5 | 118 | 13.1 |
| | | 7 m | 7.0 | 86.5 | 10.0 |
| | | 8 m | 5.9 | 20 | 2.4 |
| | | 9 m | 8.0 | 7.5 | 1.2 |
| | | 10 m | 7.0 | 6.5 | 0.9 |
| | | 13 m | 6.4 | 7.0 | 0.9 |
| Station 2 | 11/8/73 | 1 m | 20.5 | 150 | 12.9 |
| | | 3 m | 20.5 | 150 | 12.9 |
| | | 4 m | 16.3 | 182 | 16.8 |
| | | 5 m | 12.7 | 153 | 15.6 |
| | | 6 m | 9.0 | 124 | 13.9 |
| | | 7 m | 7.0 | 60 | 7.1 |
| | | 8 m | 6.0 | 9 | 1.0 |
| | | 10 m | 6.0 | 6.5 | 0.9 |
| | | 16 m | 6.0 | 6.5 | 0.9 |

TABLE I (Cont.)

| LOCATION | DATE | DEPTH | TEMPERATURE (°C) | DISSOLVED OXYGEN (% Saturation) | DISSOLVED OXYGEN ($mg\ l^{-1}$) |
|---|---|---|---|---|---|
| NORMAN | 10/8/73 | 1 m | 23.7 | 135 | 11.4 |
| | | 3 m | 21.8 | 135 | 11.6 |
| | | 4 m | 17.2 | 174 | 16.5 |
| | | 5 m | 11.5 | 144 | 15.0 |
| | | 6 m | 9.0 | 110 | 12.2 |
| | | 7 m | 7.5 | 84 | 9.6 |
| | | 8 m | 7.0 | 68 | 7.9 |
| | | 9 m | 6.2 | 54 | 6.4 |
| | | 10 m | 6.0 | 44 | 5.3 |
| | | 11 m | 5.8 | 37 | 4.5 |
| | | 12 m | 5.3 | 33 | 4.1 |
| | | 13 m | 5.2 | 22 | 2.6 |
| | | 14 m | 7.0 | 26 | 2.9 |
| | | 15 m | 7.0 | 20.5 | 2.4 |
| | | 16 m | 6.0 | 17.5 | 2.2 |
| | | 17 m | 6.5 | 16 | 2.0 |
| | | 18 m | 7.1 | 16 | 2.0 |
| PUMPHOUSE | 10/8/73 | 1 m | 20.8 | 120 | 10.4 |
| | | 2 m | 20.5 | 118 | 9.9 |
| | | 3 m | 20.0 | 118 | 10.0 |
| | | 4 m | 19.0 | 115 | 10.3 |
| | | 5 m | 17.5 | 102 | 9.3 |
| | | 6 m | 15.0 | 94 | 9.2 |
| | | 7 m | 13.0 | 92 | 9.3 |

## TABLE II

### RESULTS OF CHEMICAL ANALYSES - COCHRANE AREA LAKES

| LOCATION | DEPTH | DATE | pH | ALKALINITY | CONDUCTIVITY | SODIUM | POTASSIUM | CALCIUM | MAGNESIUM | SILICA |
|---|---|---|---|---|---|---|---|---|---|---|
| COMMANDO | | | | | | | | | | |
| Station 1 | 1m | 11/8/73 | 7.96 | 70 | 371 | 24 | 4.0 | 27 | 4 | .6 |
| | 14m | 11/8/73 | 7.14 | 105 | 470 | 25 | 4.0 | 42 | 3 | 1.4 |
| Station 2 | 1m | 11/8/73 | 8.30 | 76 | 329 | 27 | 3.7 | 30 | 4 | .7 |
| | 24m | 11/8/73 | 7.25 | 103 | 452 | 29 | 3.9 | 42 | 3 | .9 |
| HECTOR | | | | | | | | | | |
| Station 1 | 1m | 11/8/73 | 8.74 | 104 | 380 | 28 | 4.6 | 26 | 9 | 1.6 |
| | 13m | 11/8/73 | 7.23 | 144 | 510 | 29 | 4.7 | 41 | 10 | 2.4 |
| Station 2 | 1m | 11/8/73 | 8.70 | 102 | 385 | 24 | 3.1 | 26 | 11 | 1.3 |
| | 16m | 11/8/73 | 6.78 | 186 | 760 | 49 | 5.0 | 48 | 16 | 4.0 |
| NORMAN | 1m | 10/8/73 | 8.45 | 69 | 200 | 3 | 3.3 | 25 | 4 | 1.4 |
| | 18m | 10/8/73 | 7.01 | 80 | 189 | 4 | 3.6 | 27 | 4 | 1.6 |
| PUMPHOUSE | 1m | 10/8/73 | 8.62 | 109 | 291 | 8 | 2.5 | 25 | 14 | 3.7 |
| | 7m | 10/8/73 | 8.69 | 118 | 302 | 8 | 2.7 | 25 | 15 | 4.3 |

Note: All values except pH (pH units) and conductivity ($\mu$mho $cm^{-1}$) expressed as mg $l^{-1}$.

## TABLE III

## RESULTS OF CHEMICAL ANALYSES - COCHRANE AREA LAKES

| LOCATION | DEPTH | DATE | PHOSPHORUS | | NITROGENS | | | | IRON | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total | Soluble | Free Ammonia | Total Kjeldahl | Nitrite | Nitrate | Total | Soluble |
| COMMANDO | | | | | | | | | | |
| Station 1 | 1m | 11/8/73 | .014 | .006 | .06 | .28 | .002 | <.01 | .05 | <.05 |
| | 14m | 11/8/73 | .11 | .014 | .24 | .78 | .49 | .41 | .75 | .05 |
| Station 2 | 1m | 11/8/73 | .008 | .004 | .04 | .26 | .001 | <.01 | .05 | <.05 |
| | 24m | 11/8/73 | .007 | .006 | .04 | .28 | .008 | .19 | .10 | <.05 |
| HECTOR | | | | | | | | | | |
| Station 1 | 1m | 11/8/73 | .036 | .003 | .03 | .63 | .002 | <.01 | .036 | .003 |
| | 13m | 11/8/73 | .16 | .11 | .95 | 1.7 | .050 | .05 | .16 | .11 |
| Station 2 | 1m | 11/8/73 | .019 | .016 | < .01 | .39 | .12 | .23 | <.05 | <.05 |
| | 16m | 11/8/73 | 1.5 | .81 | 5.2 | 9.3 | .003 | <.01 | .35 | .20 |
| NORMAN | 1m | 10/8/73 | .15 | <.001 | .04 | .48 | .002 | <.01 | .05 | <.05 |
| | 18m | 10/8/73 | .21 | .075 | .34 | 1.0 | .002 | <.01 | .65 | .40 |
| PUMPHOUSE | 1m | 10/8/73 | .047 | .045 | < .01 | .26 | .054 | .11 | <.05 | <.05 |
| | 7m | 10/8/73 | .041 | .028 | < .01 | .26 | .002 | .06 | .30 | <.05 |

NOTE: all values expressed as mg $l^{-1}$

TABLE IV

RESULTS OF SECCHI DISC - CHLOROPHYLL A MONITORING, COCHRANE AREA LAKES, 1973

| | | SECCHI DISC (m) | CHLOROPHYLL A (μg/1) |
|---|---|---|---|
| COMMANDO LAKE | | | |
| Station 1 | | | |
| June 19 | | - | 0.5 |
| 25 | | 7.4 | 0.8 |
| July 10 | | 3.9 | 0.8 |
| 23 | | 4.2 | 1.4 |
| Aug. 1 | | 3.9 | 0.6 |
| 8 | | 3.3 | 1.5 |
| 13 | | 4.8 | 1.8 |
| | Mean | 4.6 | 1.0 |
| Station 2 | | | |
| June 19 | | 8.7 | 0.7 |
| 25 | | 6.6 | 0.8 |
| July 10 | | 4.2 | 1.5 |
| 23 | | 4.5 | 2.5 |
| Aug. 1 | | 3.6 | 1.1 |
| 8 | | 4.8 | 1.4 |
| 13 | | 5.4 | 2.0 |
| | Mean | 5.4 | 1.4 |

TABLE IV (cont.)

| | | SECCHI DISC | CHLOROPHYLL A (µg/l) |
|---|---|---|---|
| **HECTOR LAKE** | | | |
| June 12 | | 3.6 | 4.4 |
| 19 | | 5.0 | 8.6 |
| 25 | | 3.3 | 10.5 |
| July 5 | | 2.7 | 1.3 |
| 10 | | 2.4 | 6.2 |
| 23 | | 3.9 | 5.6 |
| Aug. 1 | | 3.6 | 3.9 |
| 8 | | 2.7 | 4.8 |
| 13 | | 3.6 | 2.7 |
| | Mean | 3.4 | 5.3 |
| **NORMAN LAKE** | | | |
| June 12 | | 2.4 | < 1.0 |
| 19 | | 4.6 | 2.8 |
| 25 | | 4.5 | 2.5 |
| July 8 | | 3.9 | 0.8 |
| 10 | | 4.8 | 1.7 |
| 23 | | 3.2 | 2.7 |
| Aug. 8 | | 3.0 | 2.0 |
| 13 | | 4.2 | 2.6 |
| 18 | | 3.0 | 3.0 |
| | Mean | 3.7 | 2.1 |
| **PUMPHOUSE LAKE** | | | |
| June 19 | | 3.8 | 1.1 |
| July 5 | | 3.4 | 0.6 |
| 10 | | 4.2 | 0.8 |
| 23 | | 4.5 | 1.0 |
| Aug. 1 | | 4.2 | 0.3 |
| 13 | | 5.1 | 11.0 |
| | Mean | 4.2 | 2.5 |